

REMARKS

The claims under consideration in the case are 1, 4-28, 30, 31, 34, 36-49, and 69-70. Claims 50-68 remain withdrawn due to the Requirement for Restriction.

Support for the amendment to Claims 1, 23, 36, 38, and 70 is found in the Specification at least at Page 12, paragraph 00043, at Page 23, paragraph 00077, and in Example 1, paragraph 000125. The amendment to Claims 38 and 69 removes "a)", which is unnecessary in light of the absence of other labels. Support for new Claims 71-75 is found in the Specification at least at Page 21, paragraphs 00068-00069. No fees are believed to be due for these new claims, due to the number of claims that have been cancelled in the case.

The Examiner's responses to Applicants' arguments in the Final Office Action and in the Advisory Action are appreciated, and will be discussed below in the context of the §103 rejection, to which they pertain.

Rejection under §103 over U.S. 4,228,297

Claims 1, 4-28, 30, 30, 34 and 36-49, and 69-70 are rejected under 35 U.S.C. §103(a) as obvious over Haeberli et al. (US 4,228,297) in view of Grant et al. (*Chemical Dictionary*, 1990, p. 11-12). Applicants respectfully request reconsideration and withdrawal of this rejection.

As to the teachings of Haeberli et al. regarding the catalyst, Applicants' point was that Haeberli et al. overwhelmingly teaches that two different catalysts should be used, even though Haeberli et al. states that "The second alkaline catalyst may be selected from the classes of compounds listed above for the first alkaline catalyst" (column 9, lines 1-3).

There is no suggestion in the cited references, either alone or in combination, of using aqueous phosphoric acid in place of acetic acid, much less for effecting a clean separation of the salts formed by the neutralization from the reaction product mixture. The cited references do not hint at the benefits of using phosphoric acid in the claimed esterification process.

Haeberli et al. is fundamentally different than the presently claimed invention in ways which preclude the obviousness of the present claims.

As noted on Page 5 of the Office Action of April 16, 2009, a difference between Haeberli et al. and the present claims is the use of acetic acid in Haeberli et al. while the present case uses aqueous phosphoric acid to neutralize the catalyst. The Office Action further states that both phosphoric acid and acetic acid are well-known, citing Grant et al., and concludes that because acetic acid and phosphoric acid are both well-known, it is obvious to use one in place of the other. However, this overlooks the chemical differences of these two acids. Phosphoric acid is a strong acid, while acetic acid is a weak organic acid. In this connection, see Lewis, Jr., *Hawley's Condensed Chemical Dictionary*, 13th ed., 1997, pages 14-15, attached to this Response as Exhibit A. Since acetic acid and phosphoric acid are quite different chemically, there is no motivation to use phosphoric as an alternative to acetic acid.

Another difference between the presently claimed invention and Haeberli et al. is the nature of the products formed in each. The esterification products of the present claims are liquids at or close to room temperature (*e.g.*, less than about 50°C), while those of Haeberli et al. are solids. In Haeberli et al., the product of Example 1 has a melting point of 71.5°C; the product of Example 2 has a melting point of 105°C; the Example 3 product has a melting point of 50°C; and the Example 4 product has a melting point of 110-125°C. Thus the present claims and Haeberli et al. are directed to esterification products that have different properties.

To be clear regarding the neutralization step, in the presently claimed processes, aqueous phosphoric acid is added to the reaction mixture, which is stirred to ensure contact, and then water is removed from the mixture. Upon removal of water, a precipitate forms, which precipitate is the salt(s) formed in the neutralization reaction; the esterification product is a liquid. In contrast, in Haeberli et al., the catalyst is neutralized with acetic acid, and the esterification product is crystallized (precipitated) from a suitable solvent (column 9, lines 29-34). See in this connection Example 1 of Haeberli et al., where it is stated

[T]he vacuum was then released with nitrogen, and the reaction mass was cooled to 70°C and acidified with 3.0 g of glacial acetic acid. 132 g of ethyl alcohol were added to the melt, and the resultant solution was clarified. The filtrate was cooled

to 28°C and seeded with 0.5 g of thio-bis-{ethylene-3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate}. The reaction product crystallized. (Column 10, lines 47-55, emphases added.)

In the Office Action of April 16, 2008, at the top of Page 6, the above passage is quoted, and it is incorrectly inferred therein that the salts formed by the neutralization precipitated. In this connection, alkali metal acetates are known to be soluble in alcohol; see the relevant entries for lithium acetate, potassium acetate, and sodium acetate from the *CRC Handbook*, 63rd ed., Pages B-113, B-130, and B-145, attached to this Response as Exhibit B. Thus, the filtration in Haeberli et al. must have removed some other solid impurity.

Furthermore, several benefits are obtained in the present case, at least some of which are a result of using aqueous phosphoric acid:

- A precipitate is formed without need for addition of solvent or other reagents.
- The precipitated salts are easily removed from the liquid esterification product.
- Because a solvent addition is not needed to effect precipitation, the process can be conducted in smaller reactors. The presently claimed process employs a very small amount of water (which is nonhazardous). Haeberli et al. uses a large excess of ethyl alcohol, from which the esterification product is crystallized. More particularly, in Example 1 of Haeberli et al., the amount of ethanol (132 g) is 42.2% of the total weight of reagents used in the process therein. In the present case, Example 1 utilizes 34.7 g of water, which is only 4.4% of the total weight of reagents used in the process. Thus, the present invention provides a substantial reduction of solvent use and of cost. Further, the reduction in solvent usage in turn allows the manufacture of more product in a particular reactor; in other words, more product can be produced per unit volume of reaction mass.
- Nearly complete removal of the catalyst metal from the esterification product has been achieved as shown in Example 3 (Page 42, paragraphs 000138-000139), where only 2.3 ppm potassium remained in the esterification product, a removal of more than 99.9% of the potassium.
- High yields of the esterification product are obtained. Applicants' Example 6 (Pages 46-47, paragraphs 000158-000165) shows a 97.4% isolated yield, based on 2,6-di-*tert*-butylphenol (the limiting reagent in Example 6). In this context, the highest isolated yield in

Haeberli et al. is 87% (Example 3), though Applicants maintain their position that Haeberli et al. is not directly comparable to the presently claimed invention.

- There is a significant reduction in the amount of waste solids produced, greater than 60% in comparison to prior processes. The claimed process typically generates waste solids on the order of between about 0.65% and 1.02% by weight, based on the phenolic ester product; by comparison, other reported methods generate as much as 2.70% solids (Specification, Page 12, paragraph 00045).

The Examiner has repeatedly asked for unexpected results. At least some, if not all, of the above benefits of the presently claimed invention constitute unexpected results. Similarly, the Examiner has also reiterated a suggestion to make a side-by-side comparison of the presently claimed invention to the process disclosed in Haeberli et al. To the extent possible, the relevant portions of Haeberli et al. were discussed with (compared to) each of the above beneficial features of the present invention.

While a true side-by-side comparison is not really feasible since the Haeberli et al. esterification product is a solid and the claimed process' esterification product is a liquid, in the spirit of a more complete side-by-side comparison, Example 7 of the present case is highlighted. In Example 7, a product mixture made (to that point) in accordance with the present invention was combined with acetic acid (rather than phosphoric acid) to neutralize the catalyst, as follows:

combined reaction mixture with acetic acid (1.55 g; mixture became yellow and cloudy);
water was added (10.3 g);
water was stripped (mixture became hazy);
more acetic acid was added (1.55 g);
mixture was washed twice with water (182 g, 177 g; water washes were discarded); and
organic layer was stripped at 20 mmHg and 120°C.

Some observations regarding this neutralization in Example 7 can be made. First, as mentioned in previous Responses, no precipitate was formed; thus acetic acid does not function in quite the same way in the processes of the present invention that aqueous phosphoric acid does. The initial amount of acetic acid, 0.375 mole, is enough to neutralize the catalyst (0.037 mole). Upon addition of more acetic acid, a total of 0.63 mol, a 70% excess, had been used. Thus a large excess of acetic acid is not enough to cause precipitation of the salts formed by the neutralization reaction. The isolated yield in Example 7 based on 2,6-di-tert-butyl-phenol is 100.3%,

suggesting that the separation of the salts from the esterification product is not clean; an impurity is present.

A feature of the process in Haeberli et al. which has no equivalent in the processes of the present invention is the organic liquid waste produced by the neutralization/workup step. Haeberli et al. uses a large excess of ethyl alcohol in order to separate the salts of neutralization from the esterification product, and to isolate the esterification product as a solid. This results in the formation of organic waste composed of the recovered ethyl alcohol, which contains the salts from neutralized catalyst and lost product that did not crystallize out of the ethyl alcohol. The large amount of waste is both costly and an environmental issue. Specifically, it is again noted that in Example 1 of Haeberli et al., the amount of ethanol (132 g) is 42.2% of the total weight of reagents used in the process therein.

In the Advisory Action at Page 4, second paragraph, it is stated that "the only role of acid is to neutralize the base in the process." The primary role of the acid is to neutralize the base (catalyst). It should be clear from the discussion throughout this Response that the salts formed in the neutralization reaction are desirably separated from the esterification product, and thus, a secondary consideration is the fate of the salt(s), that it would not have been obvious to use phosphoric acid instead of acetic acid based on the combination of the cited references, and that substituting a phosphoric acid for acetic acid is not merely a matter of routine experimentation. Moreover, there was no expectation that such a modification would have been "feasible and successful as shown in the prior art" (Advisory Action, Page 4, second paragraph, penultimate line), because of such modification was **not** shown or suggested in the prior art, much less shown to be successful, and thus there would have been no expectation of success.

None of the advantages of using aqueous phosphoric acid shown in the present case are taught or suggested by the cited references. Nothing in Haeberli et al. suggests that there are any ill effects to the use of acetic acid or need for improvement in the process taught therein.

We turn now to new Claims 71-75, which are direct to a one-step esterification process. Applicants' Example 5 illustrates a one-step process of the present invention, in which the

product had a purity of 94.84% by GC analysis. Haeberli et al. does not teach or suggest a one-step process for obtaining esterification products.

In light of the foregoing amendments and remarks, the case is believed to be in condition for allowance. Prompt notification to this effect would be sincerely appreciated.

If any matters remain that require further consideration, the Examiner is requested to telephone the undersigned at the number given below so that such matters may be discussed, and if possible, promptly resolved.

Please continue to address all correspondence in this Application to Albemarle Corporation at the address of record.

Respectfully Submitted,

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Hawley's
Condensed Chemical
Dictionary

THIRTEENTH EDITION

Revised by
Richard J. Lewis, Sr.



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EXHIBIT A

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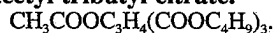
acetyl triallyl citrate.



Properties: Liquid. Boiling range 142–143C (0.2 mm), d 1.140 (20C), refr index 1.4665 (25C), flash p 365F (185C). Combustible.

Use: Cross-linking agent for polyesters; monomer for polymerization.

acetyl tributyl citrate.



Properties: Colorless, odorless liquid. Distillation range 172–174C (1 mm), pour p –60C, d 1.046 (25C), bulk d 8.74 lb/gal (25C), refr index 1.4408 (25C), viscosity 42.7 cP (25C), flash p 400F (204C). Insoluble in water. Combustible.

Derivation: Esterification and acetylation of citric acid.

Grade: Technical.

Use: Plasticizer for vinyl resins.

See "Citroflex A-4" [Morflex].

acetyl triethyl citrate.



Properties: Colorless liquid; odorless. Distillation range 131–132C (1 mm), pour p –47C, d 1.135 (25C), bulk d 9.47 lb/gal (25C), refr index 1.4386 (25C), viscosity 53.7 cP (25C), flash p 370F (187C). Slightly soluble in water. Combustible.

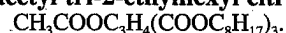
Derivation: Esterification and acetylation of citric acid.

Grade: Technical.

Use: Plasticizer for cellulose, particularly ethyl cellulose.

See "Citroflex A-2" [Morflex]; "ATEC" [Morflex].

acetyl tri-2-ethylhexyl citrate.



Properties: Liquid. Bp 225C (1 mm), flash p 430F (222C). Insoluble in water. Combustible.

Grade: Technical.

Use: Low-volatility plasticizer for vinyl resins.

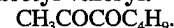
acetyltri-*n*-hexyl citrate. See "Citroflex A-6" [Morflex].

***N*-acetyltryptophan.**

Available commercially as *N*-acetyl-*L*-tryptophan, mp 185–186C; *N*-acetyl-*D*-tryptophan, mp 205C.

Use: Nutrition and biochemical research; medicine.

acetyl valeryl. (heptadione-2,3).



Properties: Yellow liquid. Combustible.

Grade: 92% pure.

Use: Cheese, butter, and miscellaneous flavors.

acetyl value. The number of milligrams of potassium hydroxide required for neutralization of acetic

acid obtained by the saponification of 1 g of acetylated fat or oil sample. Acetylation is carried out by boiling the sample with an equal amount of acetic anhydride, washing, and drying. Saponification values on acetylated and on untreated fat are determined. From the results the acetyl value is calculated. It is a measure of the number of free hydroxyl groups in the fat or oil.

ACGIH. See American Conference of Governmental Industrial Hygienists.

"Achromycin" [Cytec]. TM for tetracycline hydrochloride.

acicular. Used to describe needle-shaped crystals or the particles in powders.

acid. One of a large class of chemical substances whose water solutions have one or more of the following properties: sour taste, ability to make litmus dye turn red and to cause other indicator dyes to change to characteristic colors, ability to react with and dissolve certain metals to form salts, and ability to react with bases or alkalies to form salts. All acids contain hydrogen. In water, ionization or splitting of the molecule occurs so that some or most of this hydrogen forms H_3O^+ ions (hydronium ions), usually written more simply as H^+ (hydrogen ion).

Acids are referred to as strong or weak according to the concentration of H^+ ion that results from ionization. Hydrochloric, nitric, and sulfuric are strong or highly ionized acids; acetic acid (CH_3COOH) and carbonic acid (H_2CO_3) are weak acids. Tenth normal hydrochloric acid is 100 times as acid ($\text{pH} = 1$) as tenth normal acetic acid ($\text{pH} = 3$). The pH range of acids is from 6.9 to 1.

See pH.

When dealing with chemical reactions in solvents other than water, it is sometimes convenient to define an acid as a substance that ionizes to give the positive ion of the solvent. The common definitions of acid have been extended as more detailed studies of chemical reactions have been made. The Lowry-Brønsted definition of an acid as a substance that can give up a proton is more useful in connection with an understanding of bases (see base). Perhaps the most significant contribution to the theory of acids was the electron-pair concept introduced by G. N. Lewis around 1915.

See Lewis electron theory.

The terms *hard* and *soft* acids and bases refer to the ease with which the electron orbitals can be disturbed or distorted. Hard acids have a high positive oxidation state, and their valence electrons are not readily excited; soft acids and bases have little or no positive charge and easily excited valence electrons. Hard acids combine preferentially with hard bases, and soft acids with soft bases. Soft acids tend to accept electrons and form covalent bonds more readily than hard acids. For example, the hal-

ogen acids arranged in a series by increasing atomic weight (and decreasing chemical activity) show a progression from hard (HF) to soft (HI).

A brief outline of the major groups of acids is as follows:

Inorganic

Mineral acids: sulfuric, nitric, hydrochloric, phosphoric.

Hazard: All mineral acids are highly irritant and corrosive to human tissue.

Organic

Carboxylic (contain —COOH group)

aliphatic: acetic, formic

aromatic: benzoic, salicylic

Dicarboxylic (contain two —COOH groups)

oxalic, phthalic, sebacic, adipic

Fatty acids (contain —COOH group)

aliphatic: oleic, palmitic, stearic

aromatic: phenylstearic

Amino acids: N-containing protein components

See Lewis acid; carboxylic acid; fatty acid; amino acid; specific compounds.

1,2,4-acid. (1-amino-2-naphthol-4-sulfonic acid). $C_{10}H_7NH_2OHSO_3H$.

Properties: Pinkish-white to gray needles. Soluble in hot water; but almost insoluble in cold water.

Derivation: β -naphthol is nitrated to nitroso- β -naphthol by reaction with nitrous acid and the product treated with sodium bisulfite. Upon acidification the free sulfurous acid effects simultaneous reduction and sulfonation.

Use: Aniline dye intermediate.

1,8,2,4-acid. See Chicago acid.

acid amide. See amide.

acid ammonium sulfate. See ammonium bisulfate.

acid ammonium tartrate. See ammonium bitartrate.

acid anhydride. An oxide of a nonmetallic element or of an organic radical which is capable of forming an acid when united with water, or which can be formed by the abstraction of water from the acid molecule, or which can unite with basic oxides to form salts.

Acid Black 2.

Use: Hair color, reagent, biological stain.

acid butyl phosphate. See *n*-butyl acid phosphate.

acid calcium phosphate. See calcium phosphate, monobasic.

acid dye. An azo, triarylmethane, or anthraquinone dye with acid substituents such as nitro-, car-

boxy-, or sulfonic acid. These dyes are most frequently applied in acid soluble to wool and silk, and no doubt combine with the basic groups of the proteins of those animal fibers. Orange II (CI 15,510), black 10B, and acid alizarine blue B are examples.

acid ethylsulfate. See ethylsulfuric acid.

acid fungal protease. (fungal protease enzyme). **Properties:** Highly off-white powder.

Use: As a replacement for pepsin; chill-proofing agent for beer; in cereal treatment; feed supplement for baby pigs; rennet extender.

acid glaucine blue. See peacock blue.

acid, hard. See Lewis electron theory; acid.

acidic oxide. An oxide of a nonmetal, e.g., SO_2 , CO_2 , P_2O_5 , SO_3 , that forms an acid when combined with water.

See acid anhydride.

acidimetry. The determination of the concentration of acid solutions or of the quantity of acid in a sample or mixture. This is usually done by titration with a solution of base of known strength (standard solution); an indicator is used to establish the end point.

See pH.

acid lining. Silica brick lining used in steel-making furnaces.

acid magnesium citrate. See magnesium citrate, dibasic.

acid magnesium phosphate. See magnesium phosphate, monobasic.

acid methyl sulfate. See methylsulfuric acid.

acid mine drainage. (AMD).

Water from both active and inactive coal mines that has become contaminated with sulfuric acid as a result of hydrolysis of ferric sulfate, the oxidation product of pyrite. This is a factor in water and stream pollution, which can be corrected by use of appropriate ion-exchange resins.

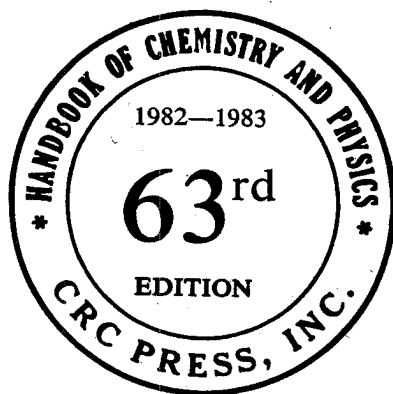
acid number. (acid value).

Determined by the number of milligrams of potassium hydroxide required for the neutralization of free fatty acids present in 1 g of fat or oil. Also the measure of free acids present in a substance.

acidolysis. A chemical reaction that is comparable to hydrolysis or alcoholysis, in which water or alcohol is used in place of the acid. It involves the

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PHYSICAL CONSTANTS OF INORGANIC COMPOUNDS (Continued)

No.	Name	Synonyms and Formulae	Mol. wt.	Crystalline form, properties and index of refraction	Density or spec. gravity	Melting point, °C	Boiling point, °C	Solubility, in grams per 100 cc		
								Cold water	Hot water	Other solvents
Lead										
1139	dithionate	PbS ₂ O ₈ ·4H ₂ O	439.38	trig, 1.635, 1.653	3.22	d		115.0 ²⁰		
1140	thiosulfate	PbS ₂ O ₃	319.32	wh cr	5.18	d		0.03		s a, Na ₂ S ₂ O ₃
1141	metatitanate	PbTiO ₃	303.09	yel, rhomb-pyr	7.52			i	i	
1142	telluride	Nat. altaite. PbTe	334.79	wh, cub	8.164 ²⁰	917				i a
1143	thiocyanate	Pb(SCN) ₂	323.35	wh, monocl	3.82	d 190		0.05 ²⁰	0.2 ¹⁰⁰	s KCNS, HNO ₃
1144	tungstate	Nat. stolzite. PbWO ₄	455.04	tetr, 2.269, 2.182	8.23			i		i HNO ₃ , s KOH
1145	tungstate	Nat. raspite. PbWO ₄	455.04	col, monocl, 2.27, 2.27, 2.30	1123			0.03		d a; i al
1146	metavanadate	Pb(VO ₃) ₂	405.07	yel powd				sl s		d HCl; s dil HNO ₃
1147	Lithium	Li	6.939	silver white, soft	0.534 ²⁰	180.54	1342	d		
1148	acetate	LiC ₂ H ₃ O ₂ ·2H ₂ O	102.01	wh, rhomb, α 1.40, β 1.50		70	d	300 ¹⁵	v s	21.5 al
1149	acetylsalicylate	LiC ₉ H ₇ O ₄	186.09	wh powd hygr, d in moist air				100		25 al
1150	metacaluminate	LiAlO ₂ (or Li ₃ Al ₂ O ₅)	65.92	wh, rhomb, 1.604, 1.614	2.55 ²⁵	1900-2000		i		
1151	aluminum hydride	LiAlH ₄	37.95	wh cr powd	0.917	d 125		d		ca 30 eth
1152	amide	LiNH ₂	22.96	col need, cub	1.178 ^{17,18}	380-400	d 750-200	s	d	sl s liq NH ₃ , al; i eth, bz
1153	antimonide	Li ₃ Sb	142.57		3.2 ¹⁷	>950		d	d	d a
1154	orthoarsenate	Li ₃ AsO ₄	159.74	wh powd, rhomb	3.07 ¹⁵			v al s		s dil ac a; i pyr
1155	azide	LiN ₃	48.96	col cr, hygr		d 115-298		66.41 ¹⁵		20.26 ¹⁵ abs al; i eth
1156	benzoate	LiC ₇ H ₅ O ₂	128.06	wh cr or powd				33 ²⁵	40 ¹⁰⁰	7.7 ²⁵ al, 10 ⁷⁵ al
1157	metaborate	LiBO ₂	49.75	wh, tricl	1.397 ^{4,7}	845		2.57 ²⁰	11.83 ²⁰	
1158	metaborate	LiBO ₂ ·8H ₂ O	193.87	col, trig	1.38 ^{14,9}	47				
1159	pentaborate	Li ₅ B ₃ O ₈ ·8H ₂ O	522.10	wh	1.72	300-350 -8H ₂ O		36.3 ¹⁵	194 ¹⁰⁰	3.9 ²⁰ al; 22 ²⁵ glycerine; i bz
1160	tetraborate	Li ₂ B ₄ O ₇	169.11	wh cr		930		2.39 ²⁰	5.45 ¹⁰⁰	i org solv
1161	borohydrate	LiBH ₄	21.78	rhomb cr	0.66	d 279		s d		s eth
1162	borohydrate	LiBH ₄	21.78	wh, orthorhomb	0.666	275 d		v al s		d al; 2.5 eth
1163	bromide	LiBr	86.85	wh, cub, deliq, 1.784	3.464 ²⁵	550	1265	145 ¹	254 ²⁰	73 ²⁵ al; 8 MeOH; s al, eth; sl s pyrid
1164	bromide, dihydrate	LiBr·2H ₂ O	122.28	wh cr		-1H ₂ O; 44		246.0 ²⁰	v s d	s al
1165	carbide	Li ₂ C ₂	37.90	wh cr or powd	1.65 ¹⁵			d		s a
1166	carbonate	Li ₂ CO ₃	73.89	wh, monocl, 1.428, 1.567, 1.572	2.11	723	d 1310 ¹⁰⁰	1.54 ²	0.72 ¹⁰⁰	i al; acet
1167	carbonate, acid	Lithium bicarbonate. LiHCO ₃	67.96	wh				5.5 ¹⁵		
1168	chlorate	LiClO ₃	90.39	col, rhomb need, deliq, α 1.63, γ 1.64	1.1190 ¹⁵ (18 % Soln)	127.6	300 d	500 ²⁷		v s al; 0.142 ²⁵ acetone
1169	chlorate	LiClO ₃ ·½H ₂ O (or ½H ₂ O)	99.39	wh, tetr, deliq		65(?)	-½H ₂ O, 90 d 290	v s	v s	v s al
1170	perchlorate	LiClO ₄	106.39	wh	2.428	236	430 d	60.0 ²⁵	150 ²⁰	152 ²⁵ al; 182 ²⁵ MeOH; 114 ²⁵ eth; 137 ²⁵ acetone
1171	perchlorate, trihydrate	LiClO ₄ ·3H ₂ O	160.44	wh, hex	1.841	95 deliq 236 (anhydr)	d 100 -2H ₂ O	130 ²⁵		72.9 ²⁵ al; 156 ²⁵ MeOH; 96.2 ²⁵ acetone; 0.096 ²⁵ eth
1172	chloride	LiCl	42.39	wh, cub, 1.662	2.068 ²⁵	605	1325-1360	63.7 ²	130 ²⁵	25.10 ²⁵ al; 42.36 ²⁵ MeOH; 4.11 ²⁵ acetone; 0.538 ²⁵ NH ₄ OH
1173	chloride, monohydrate	LiCl·H ₂ O	60.41	wh cr, hygr	1.78	-H ₂ O>98		86.2 ²⁰	s	s HCl
1174	chloroplatinate	Li ₂ PtCl ₆ ·6H ₂ O	529.78	or prism		-6H ₂ O, 180		v s	v s	v s al; i eth
1175	dichromate, dihydrate	Li ₂ Cr ₂ O ₇ ·2H ₂ O	265.90	orange-red cr, deliq	2.34 ²⁰	187 d	110 -2H ₂ O	187 ²⁰	273 ¹⁰⁰	s reacts al
1177	citrate	Li ₃ C ₆ H ₅ O ₇ ·4H ₂ O	281.98	col cr or powd, deliq		-4H ₂ O, 105		74.5 ²⁵	66.7 ¹⁰⁰	al s al, eth
1178	fluoride	LiF	25.94	wh, cub, 1.3915	2.635 ²⁰	845	1676	0.27 ¹⁵		i al; s HF
1179	fluosilicate	LiSiF ₆ ·2H ₂ O	191.99	wh, monocl, 1.300, 1.296	2.33 ¹⁵	-2H ₂ O, 100 d		73 ¹⁷		s al; i eth, acet
1180	fluosulfonate	LiSO ₃ F	106.00	wh powd		360		v s	s	v s al, eth, acet; i ligorin
1181	formate, monohydrate	H·COOLi·H ₂ O	69.97	wh, rhomb	1.46	-H ₂ O, 94	d 230	27.85 ¹⁵	57.05 ²⁰	sl s al, acet; i bz
1182	gallium hydride	LiGaH ₄	80.69	wh cr				d	d	s eth
1183	gallium nitride	LiGaN ₂	118.55	lt gr powd	3.35	d 800		d	d	s a, alk
1184	metagermanate	Li ₂ GeO ₃	134.47	monocl, 1.7	3.53 ¹⁵	1239		0.85 ²⁵		s a

PHYSICAL CONSTANTS OF INORGANIC COMPOUNDS (Continued)

No.	Name	Synonyms and Formulae	Mol. wt.	Crystalline form, properties and index of refraction	Density or spec. gravity	Melting point, °C	Boiling point, °C	Solubility, in grams per 100 cc		
								Cold water	Hot water	Other solvents
Plutonium										
p151	β	Pu	239.05	monocl	17.70	stab 122 \pm 2 to 206 \pm 3				
p152	γ	Pu	239.05	orthorhomb	17.14	stab 206 \pm 3 to 319 \pm 5				
p153	δ	Pu	239.05	cub	15.92	stab 319 \pm 5 to 451 \pm 4				
p154	δ'	Pu	239.05	tetrag	16.00	stab 451 \pm 4 to 476 \pm 5				
p155	ϵ	Pu	239.05	cub	16.51	stab 476 \pm 5 to 639.5 \pm 2				
p156	bromide, tri-	PuBr ₃	481.73	grn, orthorhomb	6.69	681		s		
p157	chloride, tri-	PuCl ₃	348.36	emerald grn, hex	5.70	760		s		s dil a
p158	fluoride, hexa-	PuF ₆	355.99	redsh-brn, orthorhomb		50.75	62.3	d		
p159	fluoride, tetra-	PuF ₄	317.99	pa brn, monocl	7.0 \pm 0.2	1037				
p160	fluoride, tri-	PuF ₃	299.00	purple, hex	9.32	1425 (\pm 3)		i		
p161	iodide, tri-	PuI ₃	622.71	bright grn, orthorhomb	6.92	777		s		
p162	nitride	PuN	256.01	blk, cub	14.25			hydrol		s HCl, H ₂ SO ₄
p163	oxalate	Pu(C ₂ O ₄) ₃ ·6H ₂ O	526.13	yel-grn				i		
p164	oxide, di-	PuO ₂	274.00	yelsh-grn, cub	11.46					sl s h conc H ₂ SO ₄ , HNO ₃ , HF
p165	sulfate	Pu(SO ₄) ₃	434.12	light pink						s dil min a
p166	sulfate, tetrahydrate	Pu(SO ₄) ₃ ·4H ₂ O	506.18	coral pink		d 280				s dil min a
p167	Polonium	Po	210.05	α -Po: simple cub; β -Po: rhbr	9.4 (for β -Po)	254	962	sl s		s dil min a; v al s dil KOH
p168	ammonium chloride	(NH ₄) ₂ PoCl ₆	458.85		2.76					
p169	tetrabromide	PoBr ₄	529.67	bright red, cub		330 (in Br atm)	360 ²⁰⁰			s al, acet; i bz, CCl ₄
p170	dichloride	PoCl ₂	280.96	ruby red, orthorhomb	6.50	subl 190				s dil HNO ₃
p171	tetrachloride	PoCl ₄	351.86	yel, monocl or tric		300 (in Cl atm)	390	s, d		s HCl; sl s al, acet
p172	tetraiodide	PoI ₄	717.67	blk cr		200 (in N atm subl)				sl s al, acet; i bz, CCl ₄
p173	dioxide	PoO ₂	242.05	red, tetr		d 500				
p174	selenate	2PoO ₃ ·SeO ₃	611.06	wh powd		>400				s dil HCl
p175	sulfate, basic	2PoO ₃ ·SO ₃	564.16	wh powd		>400, d 550				s dil HCl
p176	disulfate	Po(SO ₄) ₂	402.17	purp		d 550				i al; v s dil HCl
p177	monosulfide	PoS	242.11	blk		d 275				i al; sl s dil HCl
p178	Potassium	Kalium. K	39.0983	cub silv met	0.86 ²⁰	63.25	760	d to KOH	d	d al; s a, Hg, NH ₃
p179	acetate	KC ₂ H ₃ O ₂	98.15	wh, lust powd, deliq	1.57 ²⁵	292		253 ²⁰	492 ²²	33 al; 24.24 ²³ MeOH; s liq NH ₃ ; i eth, acet
p180	acetate, acid	K ₂ C ₂ H ₃ O ₄ ·HC ₂ H ₃ O ₂	158.20	col, need or pl, hygr		148	d 200	d	d	s al, acet
p181	acetyl salicylate	KC ₂ H ₃ O ₄ ·2H ₂ O	254.29			65				
p182	metasilicate	K ₂ AlO ₃ ·3H ₂ O	250.22	col cr				v s, d	v s, d	s alk; i al
p183	aluminosilicate	Nat. orthoclase. KAlSi ₃ O ₈ (or K ₂ O·Al ₂ O ₃ ·6SiO ₂)	278.34	wh, monocl, 1.518, 1.524, 1.526	2.56	ca 1200				
p184	aluminosilicate	Nat. microcline. KAlSi ₃ O ₈ (or K ₂ O·Al ₂ O ₃ ·6SiO ₂)	278.34	wh, tric, 1.522, 1.526, 1.530	2.54-2.57	1140-1300				
p185	aluminosilicate	Nat. muscovite, white mica. KAlSi ₃ O ₈ ·(OH) ₂ (or K ₂ O·3Al ₂ O ₃ ·6SiO ₂ ·2H ₂ O)	398.31	col, monocl, 1.551, 1.587, 1.581	2.76-2.80	d		i		
p186	aluminum metasilicate	Nat. leucite. KAlSi ₂ O ₆	218.25	col cr, 1.508	2.47	1686 \pm 5		i	i	d a
p187	aluminum orthosilicate	Nat. kaliophilite. KAlSi ₄ O ₈	158.17	col, hex or rhomb (hex→rhomb 1540°) hex: 1.532, 1.572; rhomb: 1.528, 1.536	2.5	ca 1800 (rhomb)				
p188	aluminum sulfate	Nat. kalinite. KAl(SO ₄) ₂ ·12H ₂ O	474.39	col, cub, oct or monocl, cub: 1.454, 1.4564; hex: 1.456, 1.429	1.757 ²⁰ ₁₄	92.5 -9H ₂ O, 64.5	-12H ₂ O, 200	11.4 ²⁰	v s	i al, acet; s dil
p189	amide	Potassamide. KNH ₂	55.12	col-wh, or yel-grn, hygr		335	subl 400	d	d	d al; s liq NH ₃
p190	peroxylamine sulfonate	(KSO ₃) ₂ NO	268.39	yel cr, expl				0.62 ² , d	6.6 ² , d	i al

PHYSICAL CONSTANTS OF INORGANIC COMPOUNDS (Continued)

COMPOUNDS (Continued)										
No.	Name	Synonyms and Formulae	Mol. wt.	Crystalline form, properties and index of refraction	Density or spec. gravity	Melting point, °C	Boiling point, °C	Solubility, in grams per 100 cc		
								Cold water	Hot water	Other solvents
Silver										
a168	nitrite	AgNO ₂	153.88	wh, rhomb	4.453 ²⁸	d 140		0.155 ⁵⁰	1.363 ⁵⁰	s a, a, NH ₄ OH; i al
a169	nitroplatinit	Ag ₂ [Pt(NO ₂) ₄]	594.85	yel-brn monoc pr		d 100		sl s	s	s NH ₄ OH; i al, HNO ₃
a170	nitroprusside	Ag ₂ [FeNO(CN) ₅]	431.68	lt pink				i		s KCN, NH ₄ OH, a
a171	oxalate	Ag ₂ C ₂ O ₄	303.76	col cr	5.029 ⁴	expl 140		0.00339 ¹⁸		s a, KCN, NH ₄ OH, a
a172	oxide	Ag ₂ O	231.74	br-blk, cub	7.143 ^{14,4}	d 230		0.0013 ²⁰	0.0053 ²⁰	s a, KCN, NH ₄ OH, a
a173	oxide, per	Ag ₂ O ₂ (or AgO)	247.74	gray-blk, cub	7.44	d > 100		i		s H ₂ SO ₄ , HNO ₃ , NH ₄ OH
a174	palmitate	AgC ₁₅ H ₃₁ O ₂	363.29	wh, greasy powd		209		0.0012 ²⁰	0.006 ²⁵	0.007 ¹⁸ eth; 0.006 ²⁵ al
a175	metaphosphate	AgPO ₃	186.84	wh, amorph	6.37	ca 482		i		s HNO ₃ , NH ₄ OH
a176	orthophosphate	Ag ₃ PO ₄	418.58	yel, cub	6.370 ²³	849		0.00065 ^{18,4}		s a, KCN, NH ₄ OH, NH ₃
a177	orthophosphate, mono-H	Ag ₂ HPO ₄	311.75	wh, trig	1.8036	d 110				s a, NH ₄ OH, KCN, a
a178	pyrophosphate	Ag ₄ P ₂ O ₇	605.42	wh	5.306 ^{7,8}	585		i	i	s a, NH ₄ OH, KCN, a
a179	propionate	AgC ₃ H ₅ O ₂	180.94	wh leaf or need	2.687 ²⁸			0.842 ²⁰	2.04 ²⁰	
a180	perrhenate	AgReO ₄	358.07	wh cr, tetrag or rhomb	7.05	430		0.32 ²⁰		
a181	salicylate	AgC ₇ H ₅ O ₂	244.99	wh to redsh-wh cr				sl s		s al
a182	selenate	Ag ₂ SeO ₄	358.73	wh, orthorhomb cr	5.72			0.118 ²⁰		
a183	selenide	Ag ₂ Se	294.70	thin gray pl, cub	8.0	880	d	i		s NH ₄ OH, h
a184	stearate	AgC ₁₈ H ₃₅ O ₂	391.35	wh powd amorph		205		0.006 ²⁰		HNO ₃
a185	sulfate	Ag ₂ SO ₄	311.80	wh, rhomb, 1.7583, 1.7748, 1.7852	5.45 ^{2,3}	652	d 1085	0.57 ⁵	1.411 ⁵⁰	0.006 ²⁵ al; 0.006 ²⁵ eth s a, NH ₄ OH; i al
a186	sulfide	Nat. acanthite, Ag ₂ S	247.80	gray-blk, rhomb	7.326	tr 175	d		v sl s	s KCN, conc H ₂ SO ₄ , HNO ₃
a187	sulfide	Nat. argentite, Ag ₂ S	247.80	blk, cub	7.317	825	d	8.4 x 10 ⁻¹⁵		s KCN, a
a188	sulfite	Ag ₂ SO ₃	295.80	wh cr		d 100		v al s		s a, NH ₄ OH, KCN; i HNO ₃
a189	d-tartrate	Ag ₂ C ₄ H ₄ O ₆	363.81	wh, scales	3.423 ¹⁸	d		0.2 ¹⁸	0.203 ²⁵	s a, KCN, NH ₄ OH
a190	orthotellurate, tetra-H	Ag ₄ H ₄ TeO ₆	443.40	straw yel, rhomb bipy		d > 200		i	i	s KCN, NH ₄ OH
a191	telluride	Nat. hessite, Ag ₂ Te	343.34	gray, cub	8.5	955		i	i	s KCN, NH ₄ OH
a192	tellurite	Ag ₂ TeO ₃	391.36	yel-wh ppt		250-bl 450-pa yel		i	i	s KCN, NH ₃
a193 ¹	thioantimonite	Nat. pyrrargyrite, Ag ₃ SbS ₃	541.55	red, trig, 3.084 2.881 (Li)	5.76	486		i	i	s HNO ₃
a193 ²	thioarsenite	Nat. proustite, Ag ₃ AsS ₃	494.72	scarlet red, trig, 3.088, 2.792	5.49	490		i	i	s HNO ₃
a194	thiocyanate	AgSCN	165.95	col cr		d		0.000021 ²⁸	0.00064 ¹⁰⁰	s NH ₄ OH; i a
a195	di-thionate	Ag ₂ S ₂ O ₆ ·2H ₂ O	411.90	rhomb cr, ~1.662	3.61					s Na ₂ S ₂ O ₃ , NH ₄ OH
a196	thiosulfate	Ag ₂ S ₂ O ₃	327.87	wh cr		d		sl s		s KCN, NH ₄ OH, HNO ₃
a197	tungstate	Ag ₂ WO ₄	463.59	pa yel cr				0.05 ¹⁸		1.618 conc NH ₄ OH d al; eth, bz
a198	Silver complex diamminesilver perrhenate	[Ag(NH ₃) ₂]ReO ₄	392.13	col monoc cr	3.901					
a199	Sodium	Na	22.9898	silv, met cub, 4.22	0.97	97.81 ± 0.03	882.9	d to NaOH + H ₂ 119 ⁵⁰	170.15 ¹⁰⁰	sl s al
a200	acetate	NaC ₂ H ₃ O ₂	82.03	wh gr powd, monoc, 1.464	1.528	324		76.2 ⁵⁰	138.8 ⁵⁰	2.1 ¹⁸ al; s eth
a201	acetate trihydrate	NaC ₂ H ₃ O ₂ ·3H ₂ O	136.08	col, monoc pr, eff, β 1.464	1.45	58	123, -3H ₂ O, 120			s HCl; d dil al
a202	alumina trisilicate	Nat. albite, NaAlSi ₃ O ₈ (or Na ₂ O·Al ₂ O ₃ ·6SiO ₂)	262.22	col, tricl, 1.525, 1.529, 1.536	2.61	1100		al d		
a203	metaaluminate	NaAlO ₂	81.97	wh amorph powd, hygr, 1.566, 1.595, 1.580		1800		s	v s	i al
a204	aluminum chloride	NaCl·AlCl ₃	191.78	wh-yelsh cr powd, hygr		185		s	s	
a205	aluminum meta-silicate	Nat. jadeite, Na ₂ O·Al ₂ O ₃ ·4SiO ₂	404.28	col, monoc	3.3	1000-1060		i	i	d HCl